Geologic and Geotechnical Information Required For Risk Assessments

Best Practices in Dam and Levee Risk Analysis

Part A Risk Analysis Basics

Chapter A-2

July 6, 2018

US Army Corps of Engineers

Outline

- Objectives and key concepts
- Geologic Inputs to Event Trees (example)
- Primary Geologic Contributions (seismic, hydrologic, static)
- Portraying Relevant Geologic Information Effectively
- Summary and Conclusions

Objectives

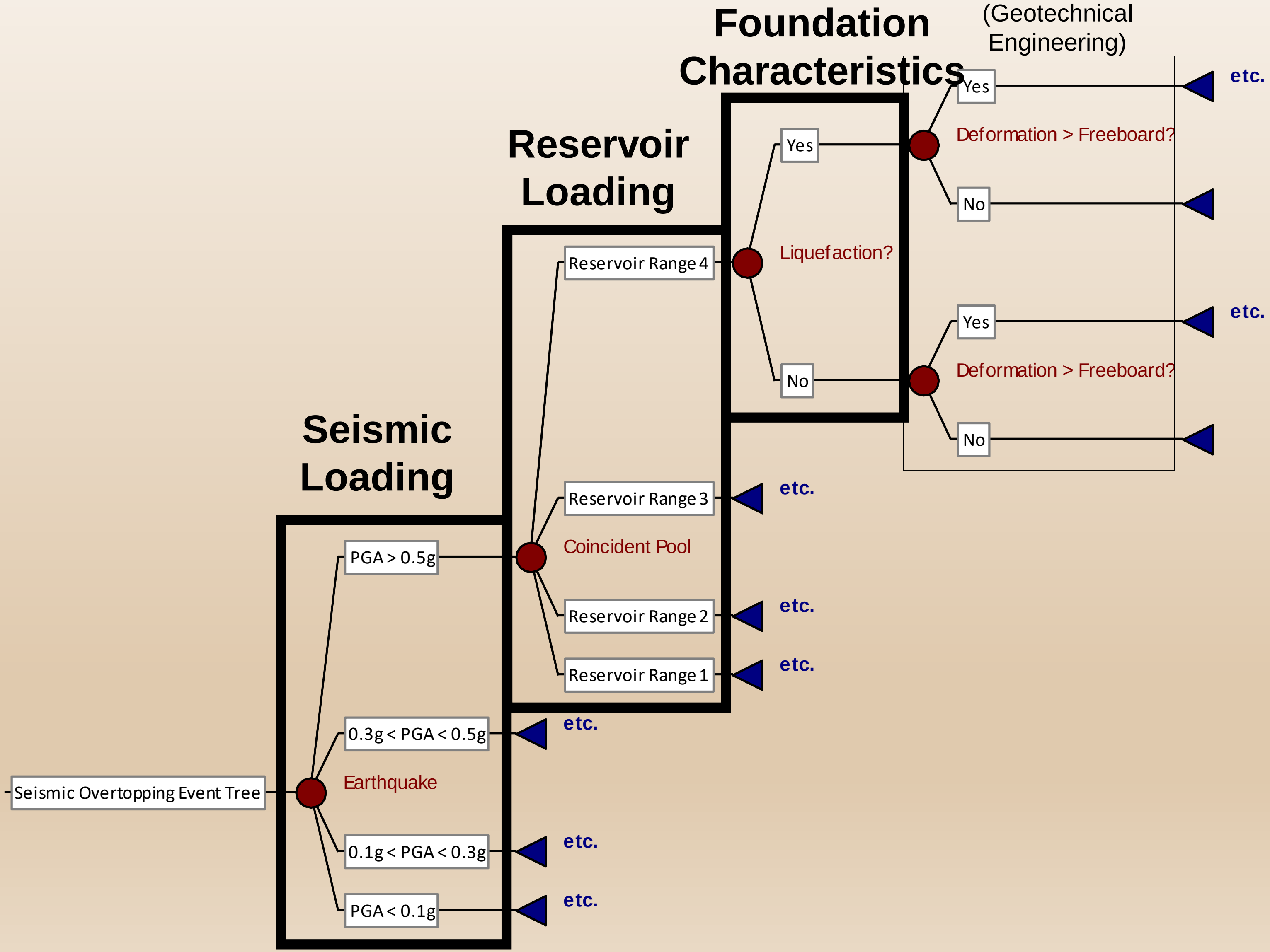
- Understand primary geologic and geotechnical contributions to risk assessment
- Summarize key geologic concepts and associated hazards that can affect dam safety and influence risk assessment
- Understand importance of compiling relevant geologic and geotechnical data and portraying information effectively for risk assessment

Key Concepts

Geologists and Geotechnical Engineers:

- Identify and Evaluate Site Characteristics and Hazards
- Contribute to Seismic, Static, Hydrologic Loading Estimates
- Constrain Uncertainties in Site Conditions and Loading
- Communicate and Participate in Risk Assessment

Event Tree for Potential Failure Mode Example: Seismic Crest Deformation



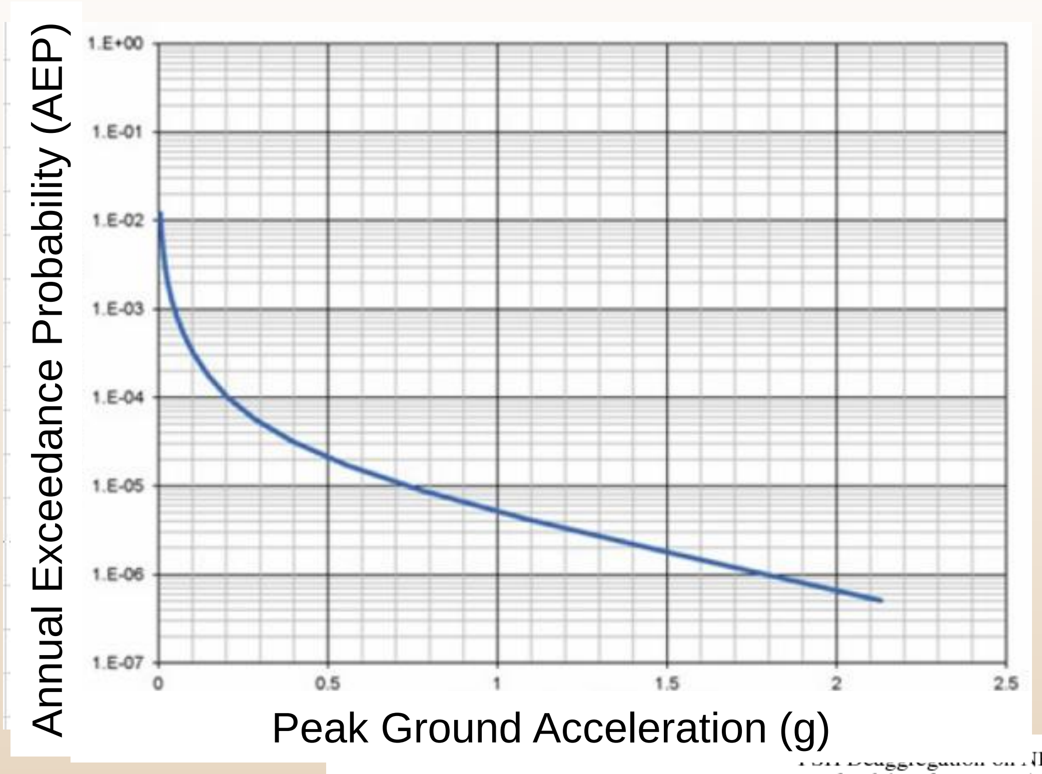
Seismic Loading

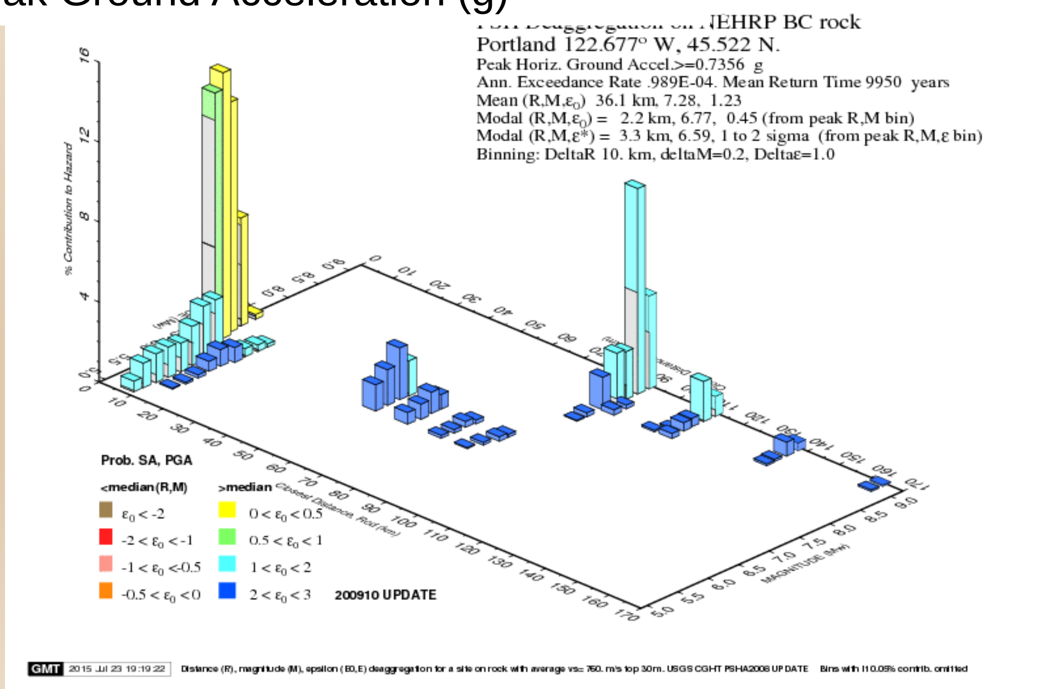
Probabilistic earthquake loadings

- Identify earthquake sources
- Characterize activity rates and magnitudes
- Estimate ground motions and exceedance rates
- Develop shaking time histories

Probabilistic fault displacement

- Define fault location, activity, width, coseismic slip
- Estimate displacement exceedance rates

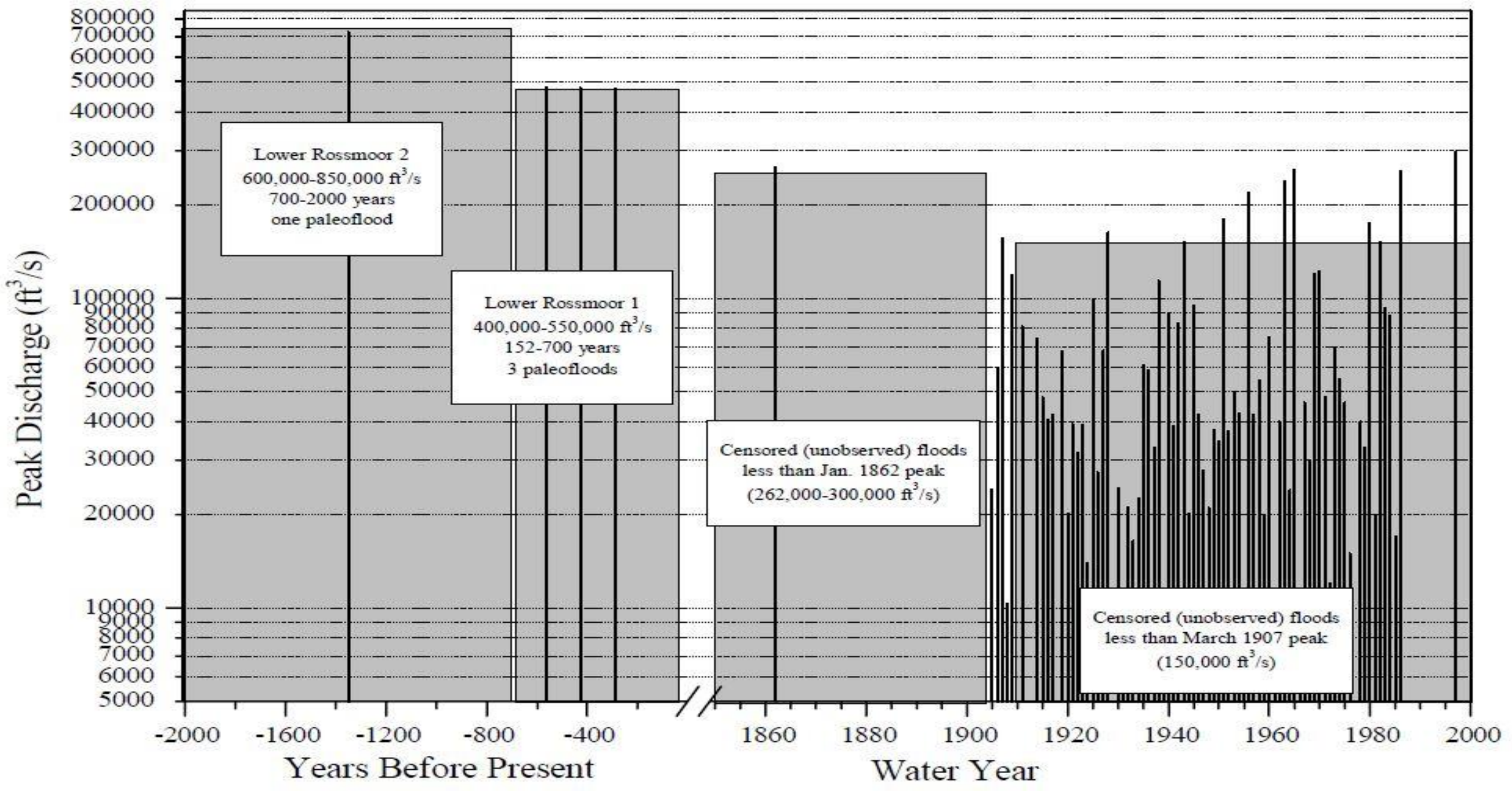




Hydrologic Loading: Streamflow Input Data

Probabilistic reservoir or levee loadings

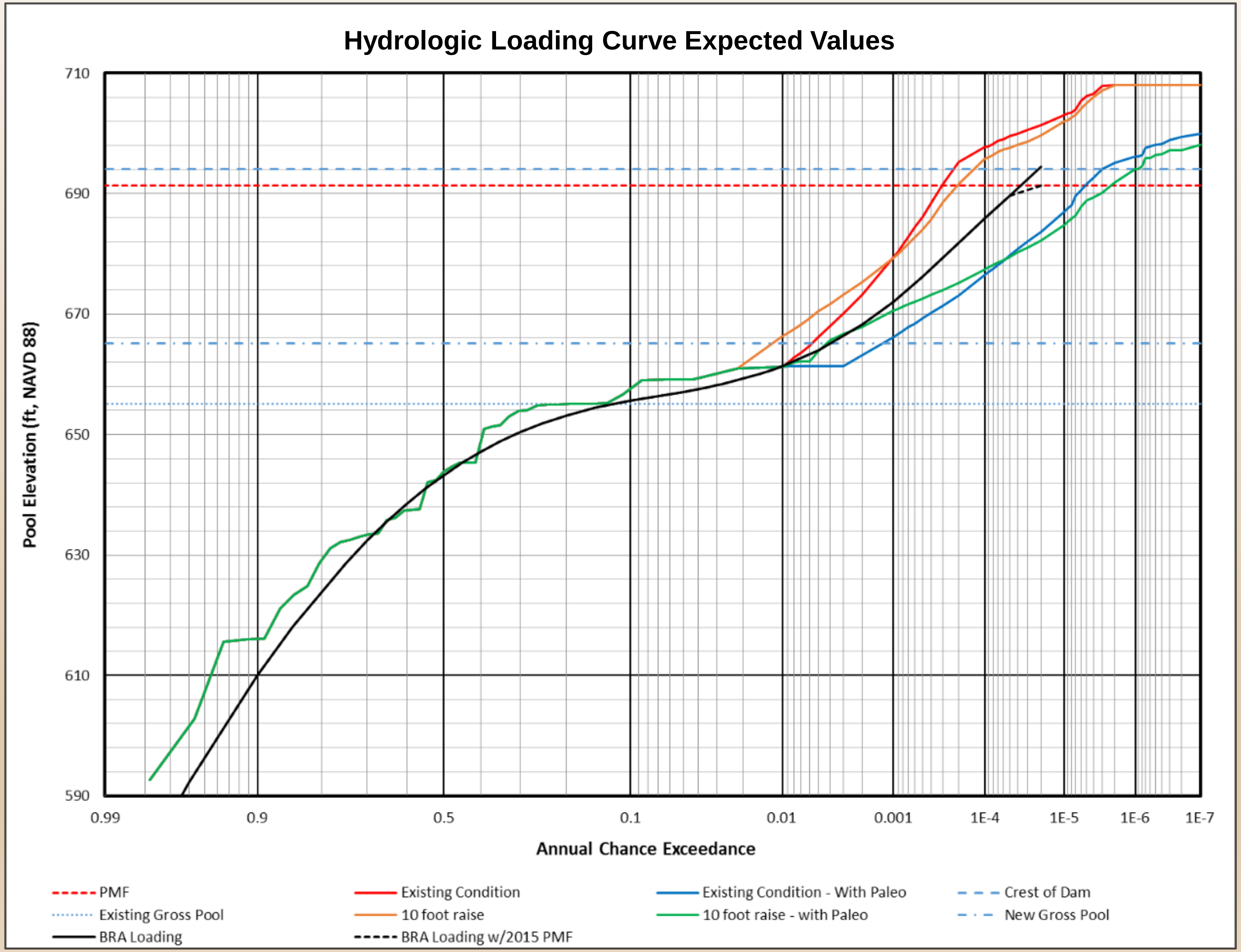
- Use gaged, historic, and paleoflood streamflow records
- Use updated meteorology
- See Best Practices Hydrology Chapter B-1



Hydrologic Loading

Probabilistic reservoir loading

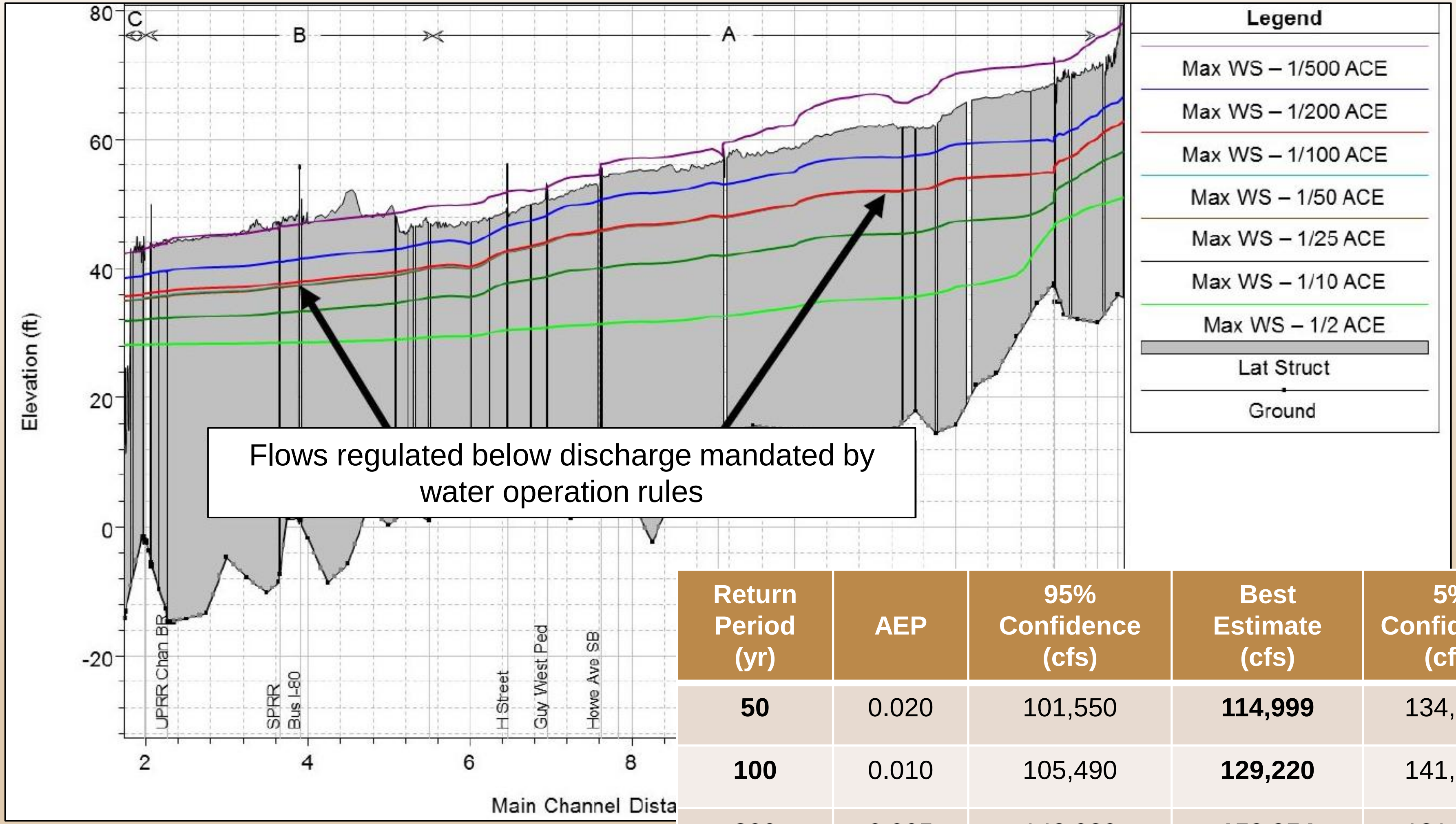
- Volume-frequency curves and pool-duration curves
- See Best Practices Hydrology Chapter B-1



Hydrologic Loading

Probabilistic levee loading

- For levees, flow frequency and stage-frequency curves
- See Best Practices Hydrology Chapter B-1



Return Period (yr)	AEP	95% Confidence (cfs)	Best Estimate (cfs)	5% Confidence (cfs)
50	0.020	101,550	**114,999**	134,250
100	0.010	105,490	**129,220**	141,290
200	0.005	143,980	**159,954**	181,790
500	0.002	244,930	**317,458**	406,710

Static Loading: Dam and Levee Foundations

Characterize **static** dam and levee site conditions

- Geologic units in foundation and abutments
- Characterize bedrock jointing/fractures/permeability
- Quantify rock / alluvial characteristics for analyses
- Characterize groundwater seepage paths

Identify / assess potential hazards in foundations:

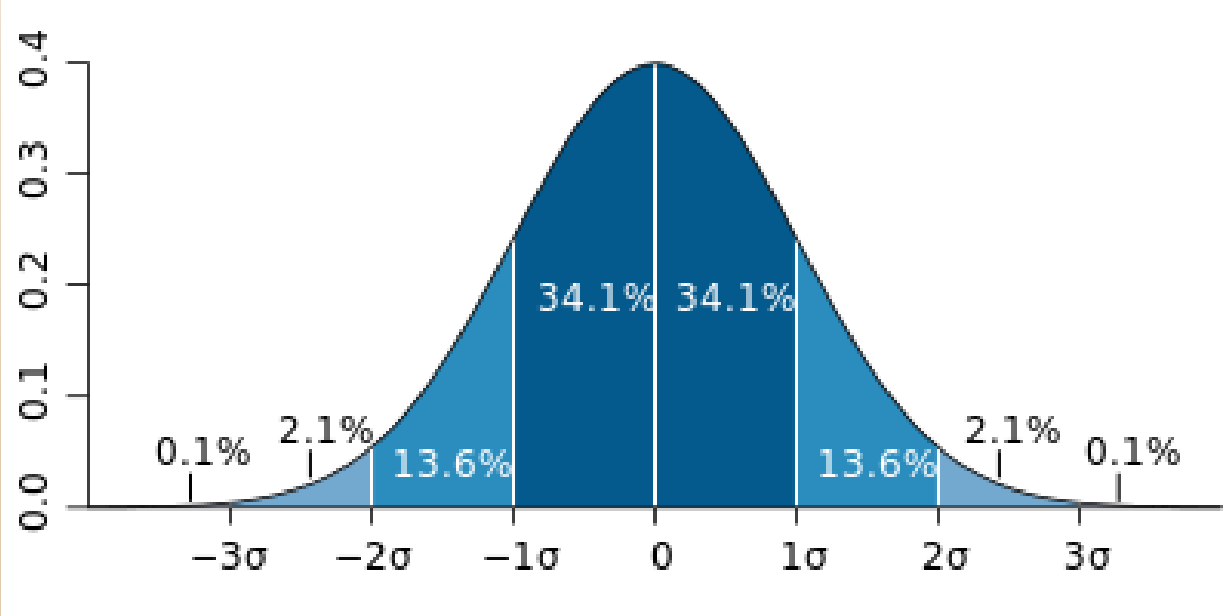
- Internal erosion of soils
  - Concentrated Leak Erosion (underseepage), other
- Bedrock dissolution
- Landslides (dam site, reservoir rim)

Mel Price Lock and Dam
and Upper Wood River Levee

Geologic and Geotechnical Contributions

What are the primary sources of uncertainty in the site hazard characterization?

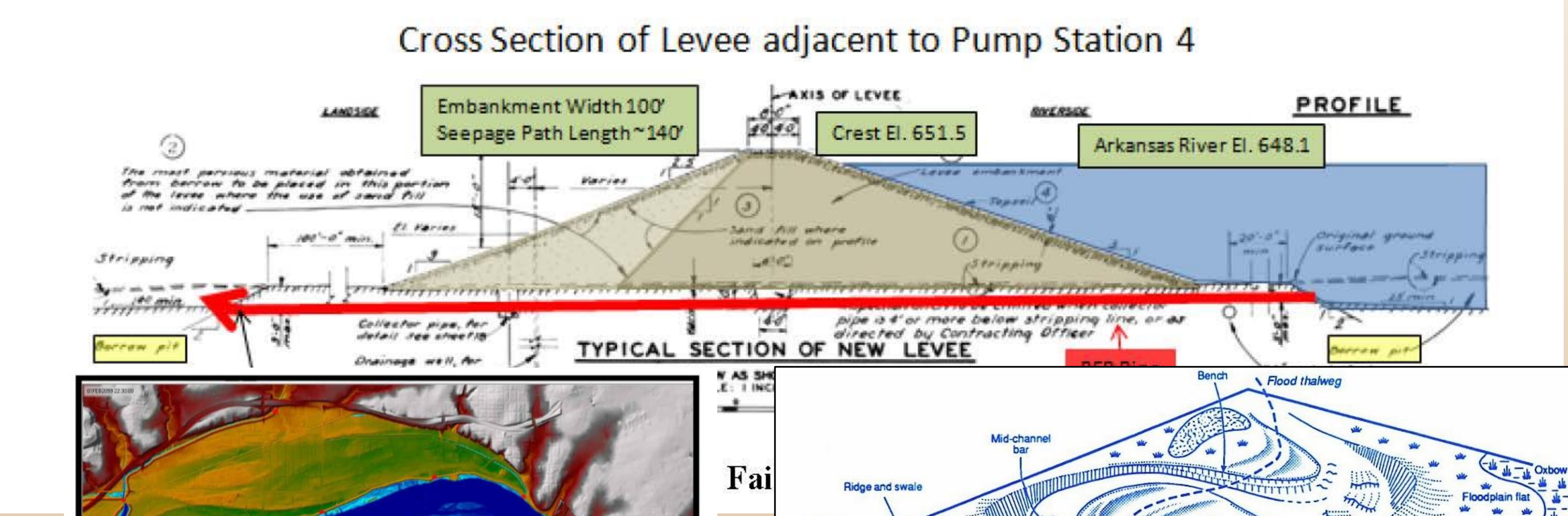
Estimate the center, body, and range of uncertainty by understanding geologic variability



Geologic and Geotechnical Contributions

Are erodible sand or silt strata continuous beneath dam / levee?

Understand depositional environments and stratigraphic models



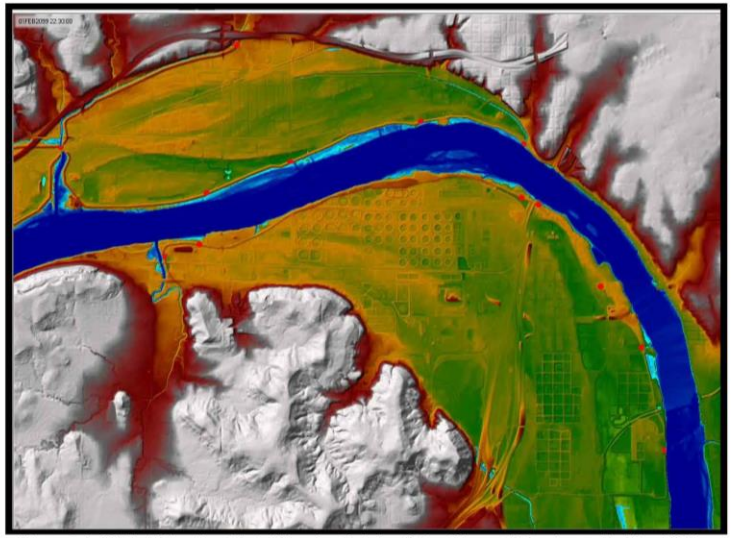


Figure 2-8: Digital Elevation Model Showing Existing Paleo Channel Margins as the Flood Plain Widens (greens and blues are lower elevations).

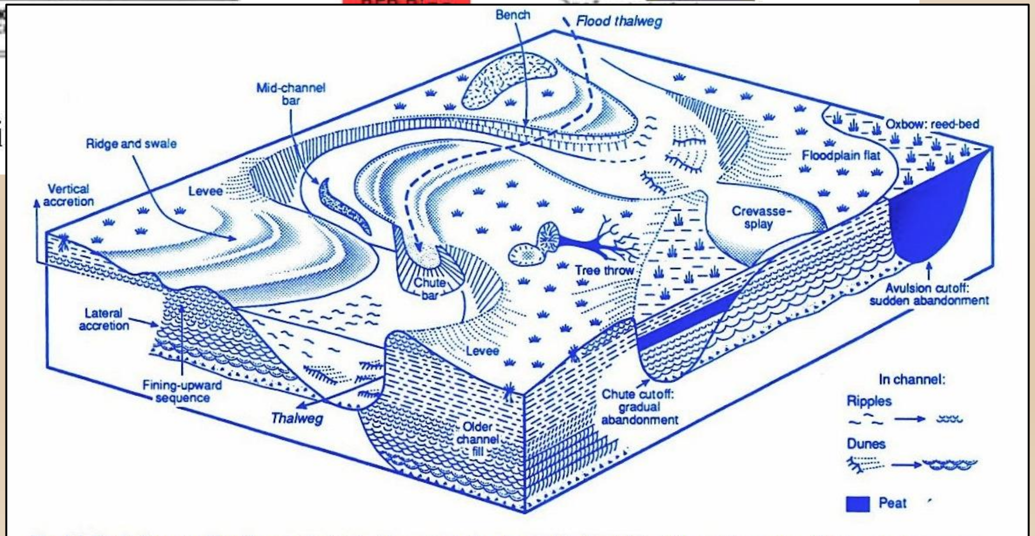
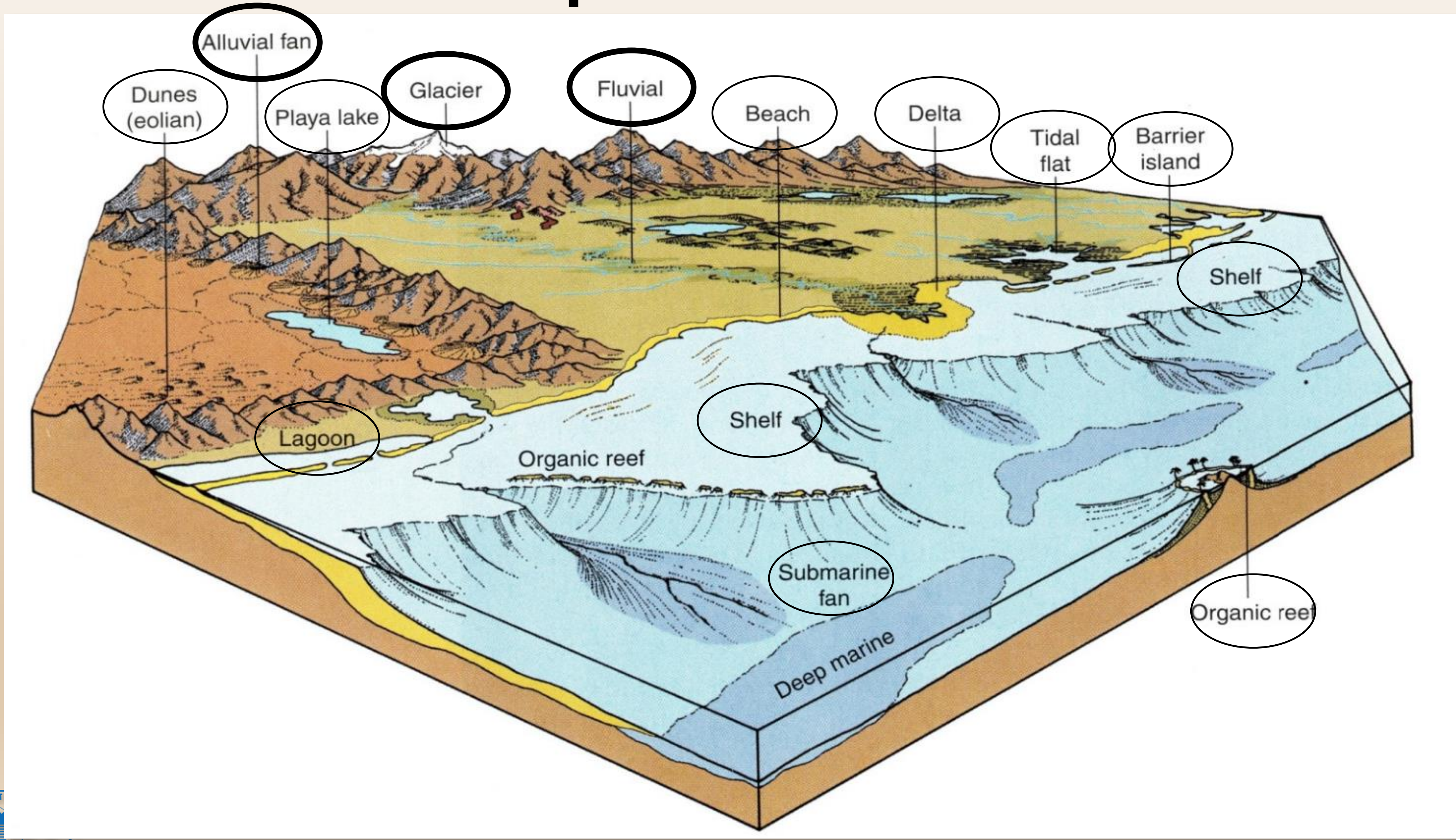


Fig. 1.1 Block diagram of landforms associated with a meandering river and its floodplain. Adapted from Allen (1965), and other sources.

Depositional Environments Control Deposit Characteristics



Sedimentary Processes Control Variability of Deposits

Name	Key Depositional Processes	Range in Sediment Grain Sizes	Relative Grain Size Variability	Relative Strata Continuity
Marine	Deep sea - Low Energy	Mud and Clay	Low to Moderate	Highly Continuous
Lacustrine	Lake - Low Energy	Fine Sand, Silt and Clay	Low to Moderate	Highly Continuous
Aeolian	Windblown	Fine Sand and Silt	Low to Moderate	Moderately to Highly Continuous
Delta	Transition Zone River → Marine or Lake	Gravel and Sand, Silt and Clay	Moderate	Highly Continuous
Fluvial	Riverine – Channel Riverine – Overbank	Sand and Gravel Sand, Silt and Clay	High to Moderate	Mod Continuous (overbank) to Discontinuous (channel)
Beach	Transition Zone Marine → Non Marine	Fine Sand to Gravel	High to Moderate	Moderately Continuous
Alluvial Fan	Water	Clay to Boulder Gravel	High	Discontinuous
Glacial	Ice-emplaced; Lacustrine High-Discharge Riverine	Clay to Boulders	High	Mod Continuous (till, lacustrine) to Discontinuous
Colluvium	Gravity	Clay to Boulders	Very High	Discontinuous
Volcanic	Varies (air, gravity)	Fine Ash to Boulders	Very High	Mod Continuous (ashfall) to Discontinuous

Geologic Processes Control Initial Density of Deposits

- Marine deposits that have remained submerged…
- Loess deposits – most recent versus older deposit that has been covered by recent
- Alluvial processes
- Glacial processes – can overrides soils and make denser than modern compaction methods, can result in ice dam lacustrine deposits such as varved clays that are very soft and highly anisotropic.
- Colluvium above the water table…

Geologic and Geotechnical Contributions

What are estimated piezometric gradients along potential seepage paths?

Understand instrumentation performance and results.

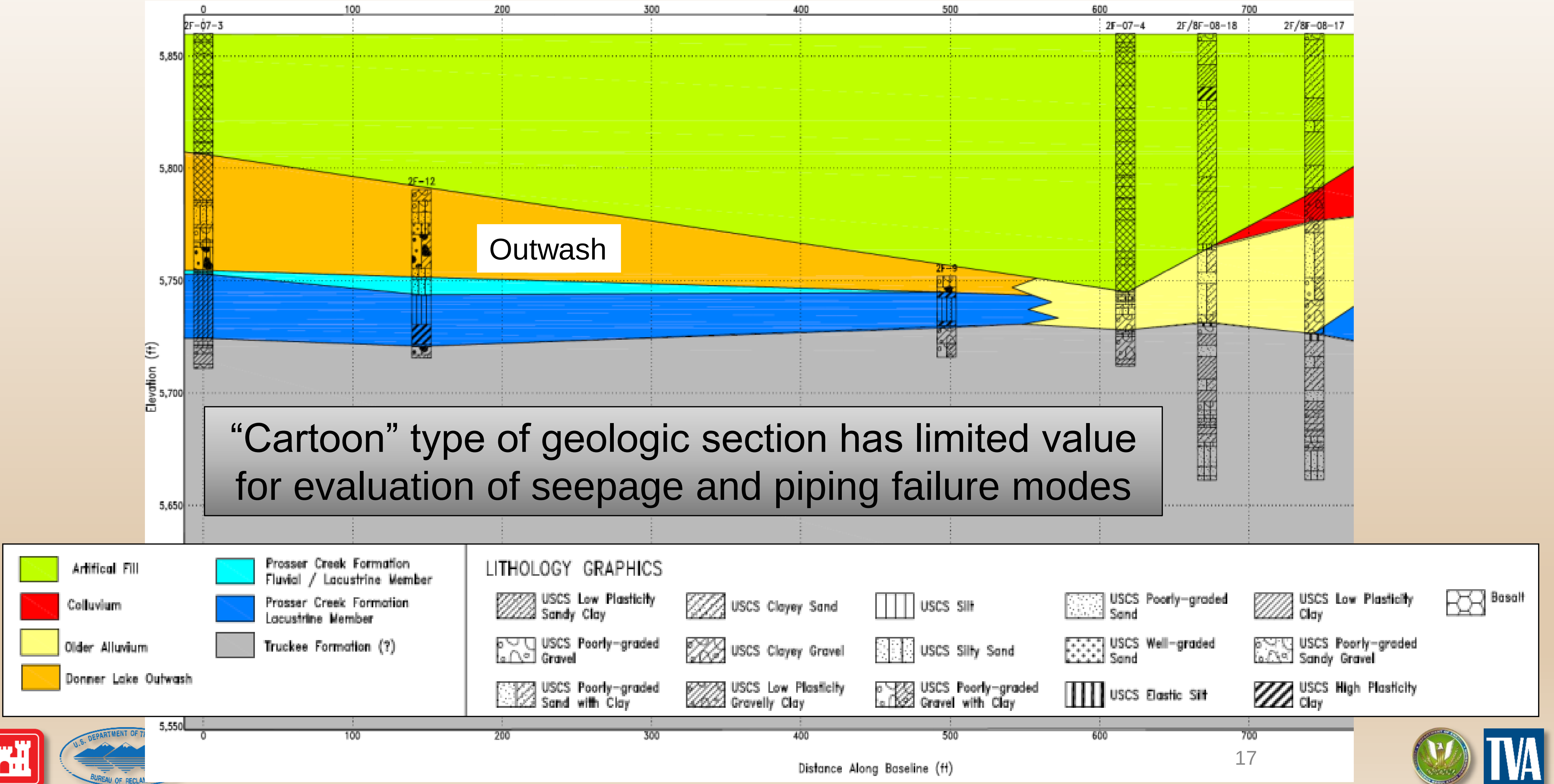
What were the dam/levee foundation conditions prior to and during construction”? how were they treated? Or consolidated by dam/levee?

Interpret geologic and geomorphic features from design documents, drawings, and construction photographs.

How likely is slope instability related to bedrock fracturing?

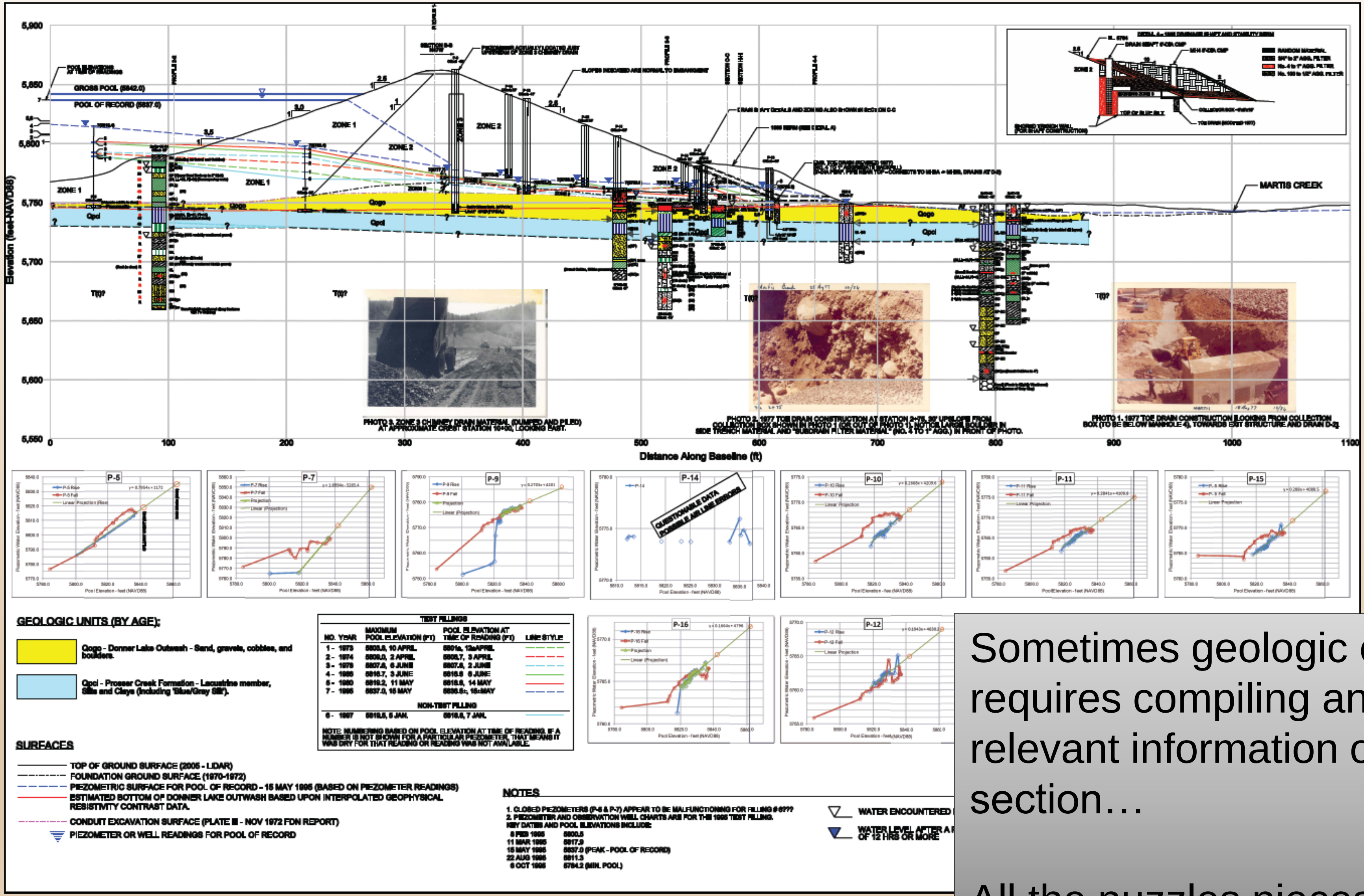
Understand rock strength characteristics and rock-mechanics-related deformation.

Example: Characterization of Foundation Materials



“Cartoon” type of geologic section has limited value for evaluation of seepage and piping failure modes

Example: Characterization of Foundation Materials

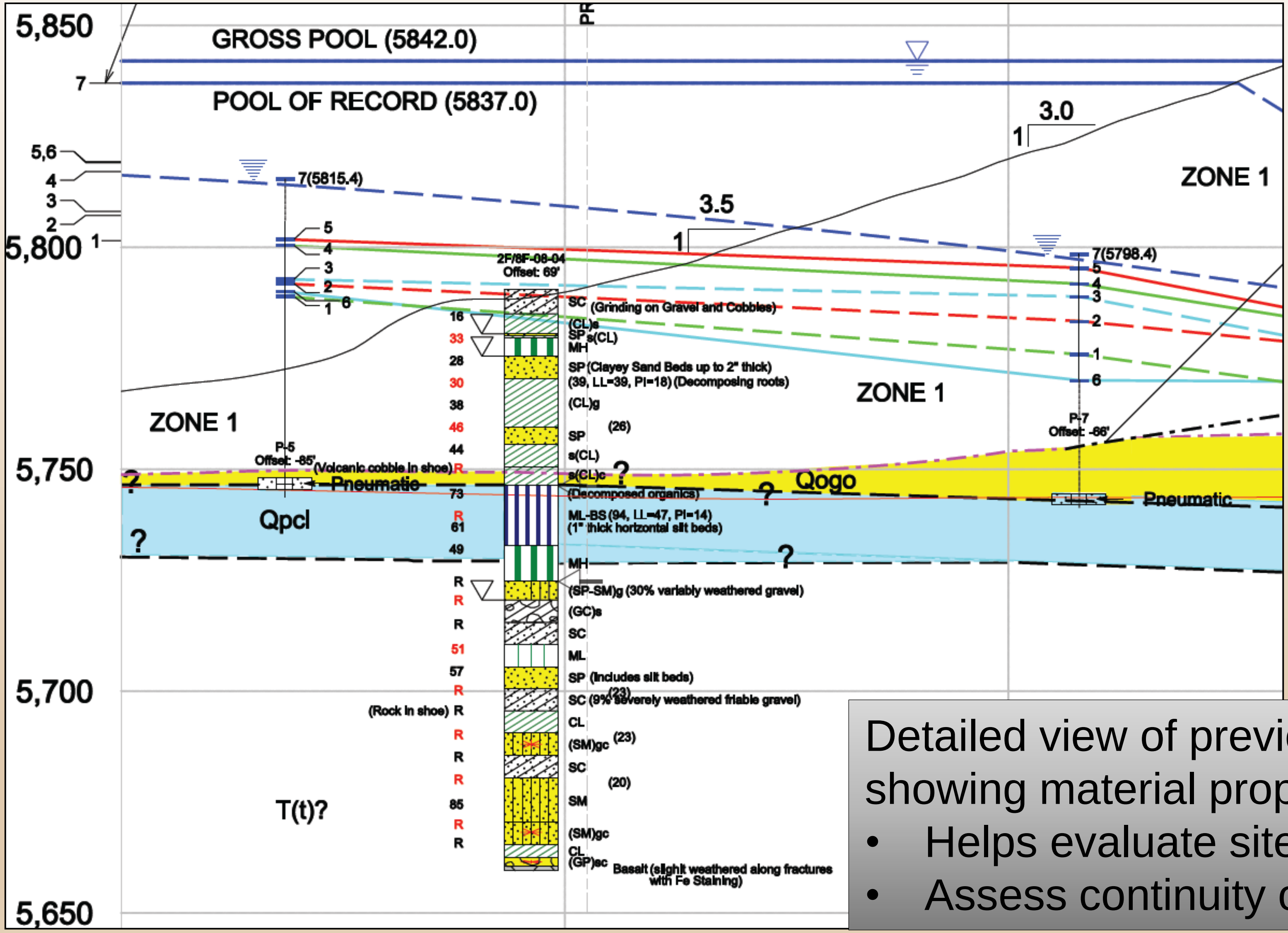


Same Project as previous slide

Sometimes geologic characterization requires compiling and portraying all relevant information on a single cross-section…

All the puzzles pieces need to be on the table….

Example: Characterization of Foundation Materials

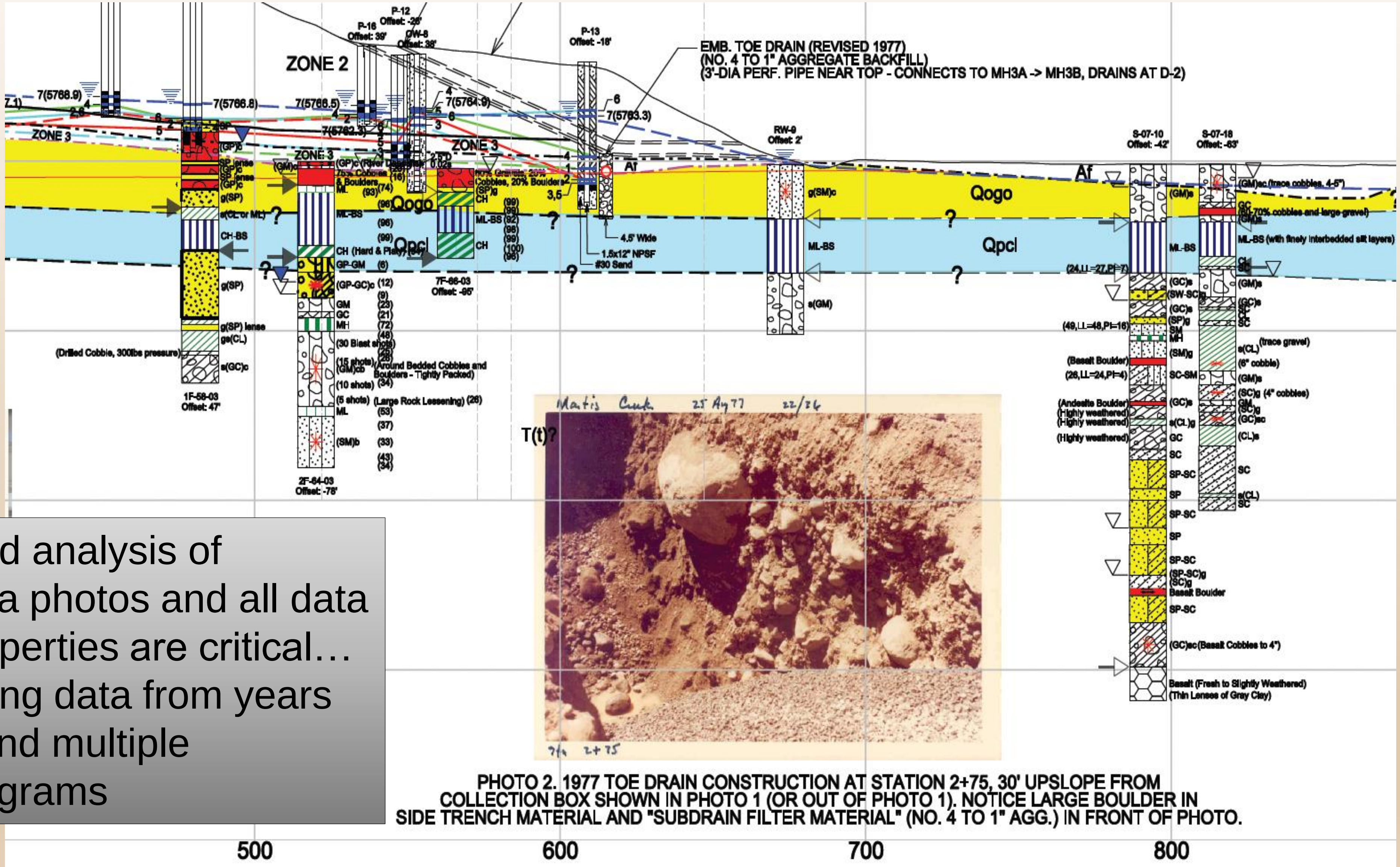


Detailed view of previous slide now showing material properties

- Helps evaluate site materials, and
- Assess continuity of sand strata.

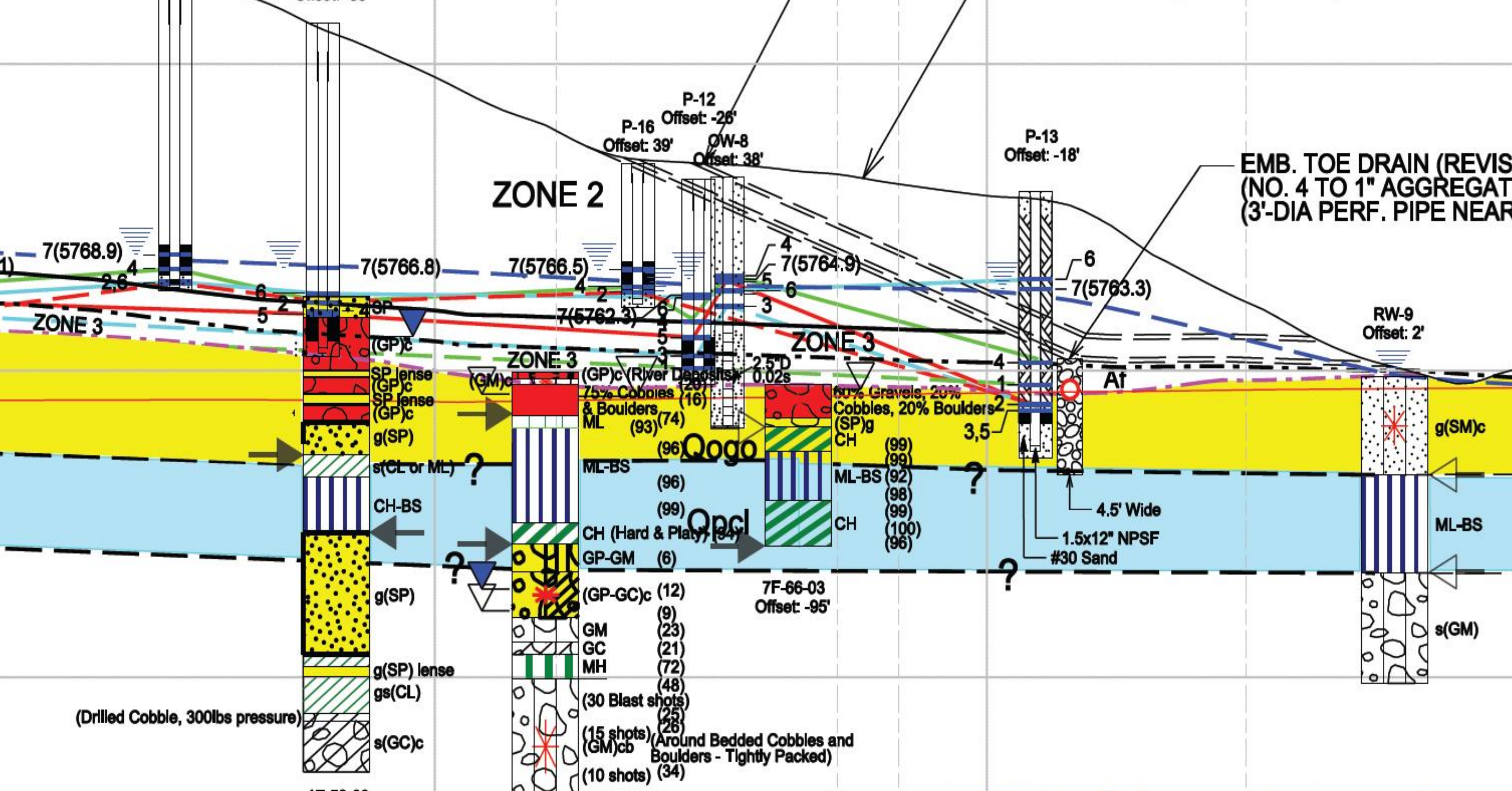
Same Project as previous slide

Example: Characterization of Foundation Materials



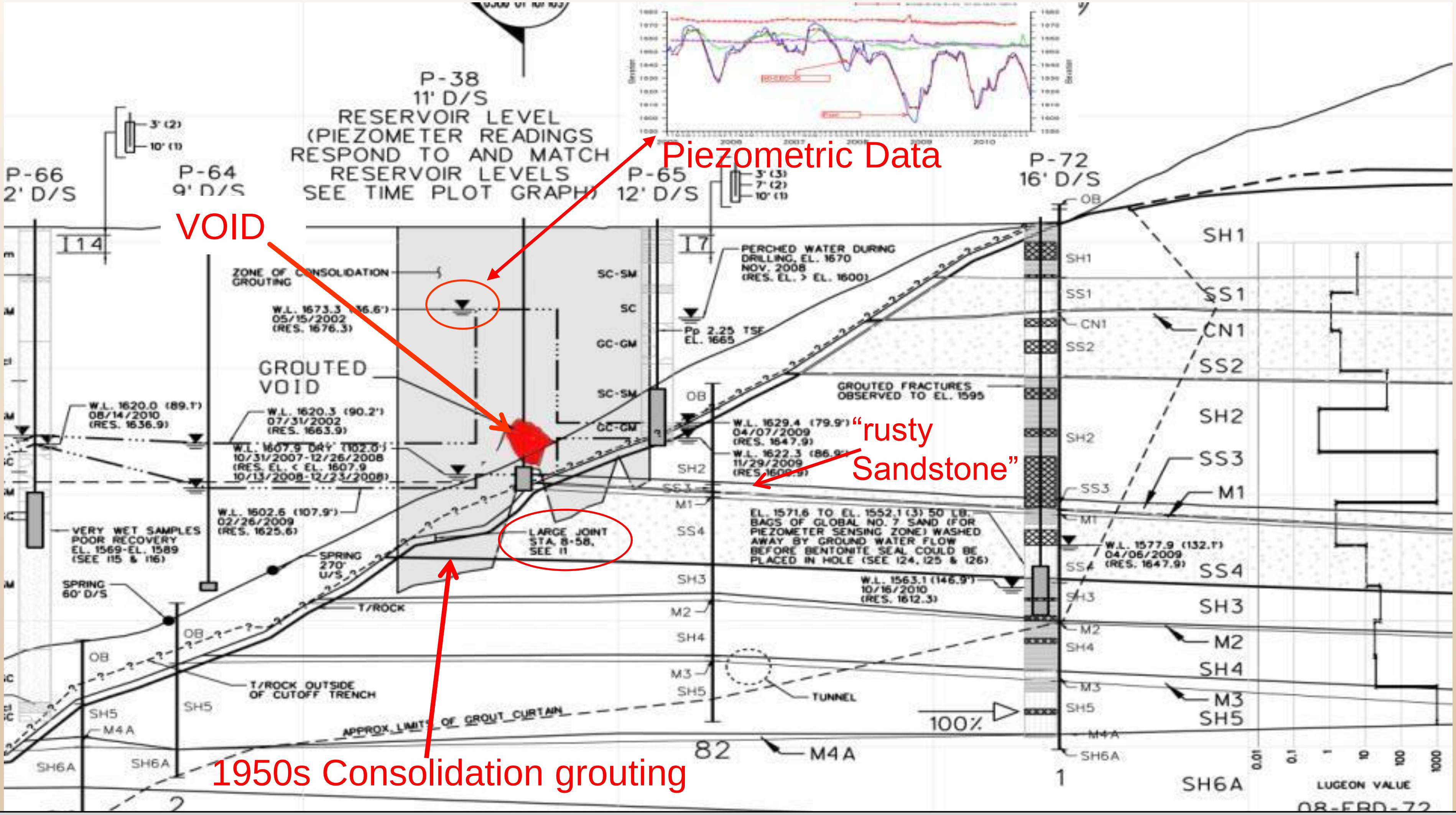
Compilation and analysis of construction-era photos and all data on material properties are critical… for understanding data from years of monitoring and multiple exploration programs

Same Project as previous slide


ZONE 2
P-16
Offset: 39'
P-12
Offset: -26'
OW-8
Offset: 38'
P-13
Offset: -18'
EMB. TOE DRAIN (REVIS
(NO. 4 TO 1" AGGREGAT
(3'-DIA PERF. PIPE NEAR
7(5768.9)
7(5766.8)
7(5766.5)
7(5764.9)
7(5763.3)
7(5762.3)
ZONE 3
ZONE 3
ZONE 3
RW-9
Offset: 2'
SP
(GP)c
SP lense
(GP)c
SP lense
(GP)c
g(SP)
s(CL or ML)
CH-BS
g(SP)
g(SP) lense
gs(CL)
(Drilled Cobble, 300lbs pressure)
s(GC)c
1F-58-03
Offset: 47'
(GM)c
(GP)c (River Deposits)
75% Cobbles
& Boulders
ML
ML-BS
CH (Hard & Platy)
GP-GM
(GP-GC)c
GM
GC
MH
(30 Blast shots)
(15 shots)
(GM)cb
(Around Bedded Cobbles and
Boulders - Tightly Packed)
(10 shots)
(5 shots)
(Large Rock Lessening)
ML
Qogo
Qpcl
2.5"D
0.02s
60% Gravels, 20%
Cobbles, 20% Boulders
(SP)g
CH
ML-BS
CH
7F-66-03
Offset: -95'
Af
4.5' Wide
1.5x12" NPSF
#30 Sand
g(SM)c
ML-BS
s(GM)


Martis Creek 25 Aug 77 22/36

Example: Characterization of Bedrock and Fractures



Geology, geotechnical engineering and instrumentation are integrated to focus on characterizing failure modes

It's Not Only Rocks and Dirt: Integration of Diverse Data Sets

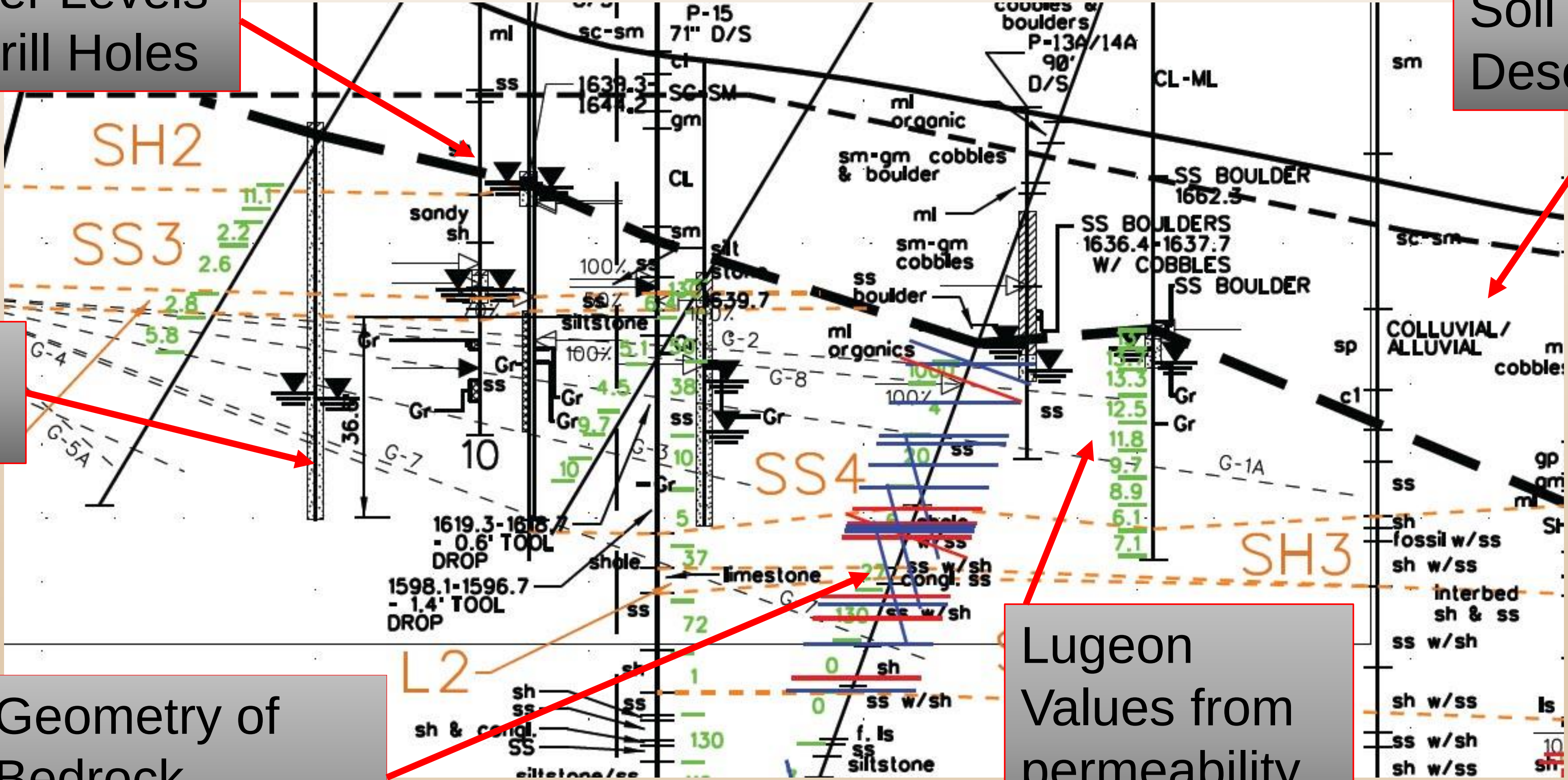
Water Levels in Drill Holes

Soil Descriptions

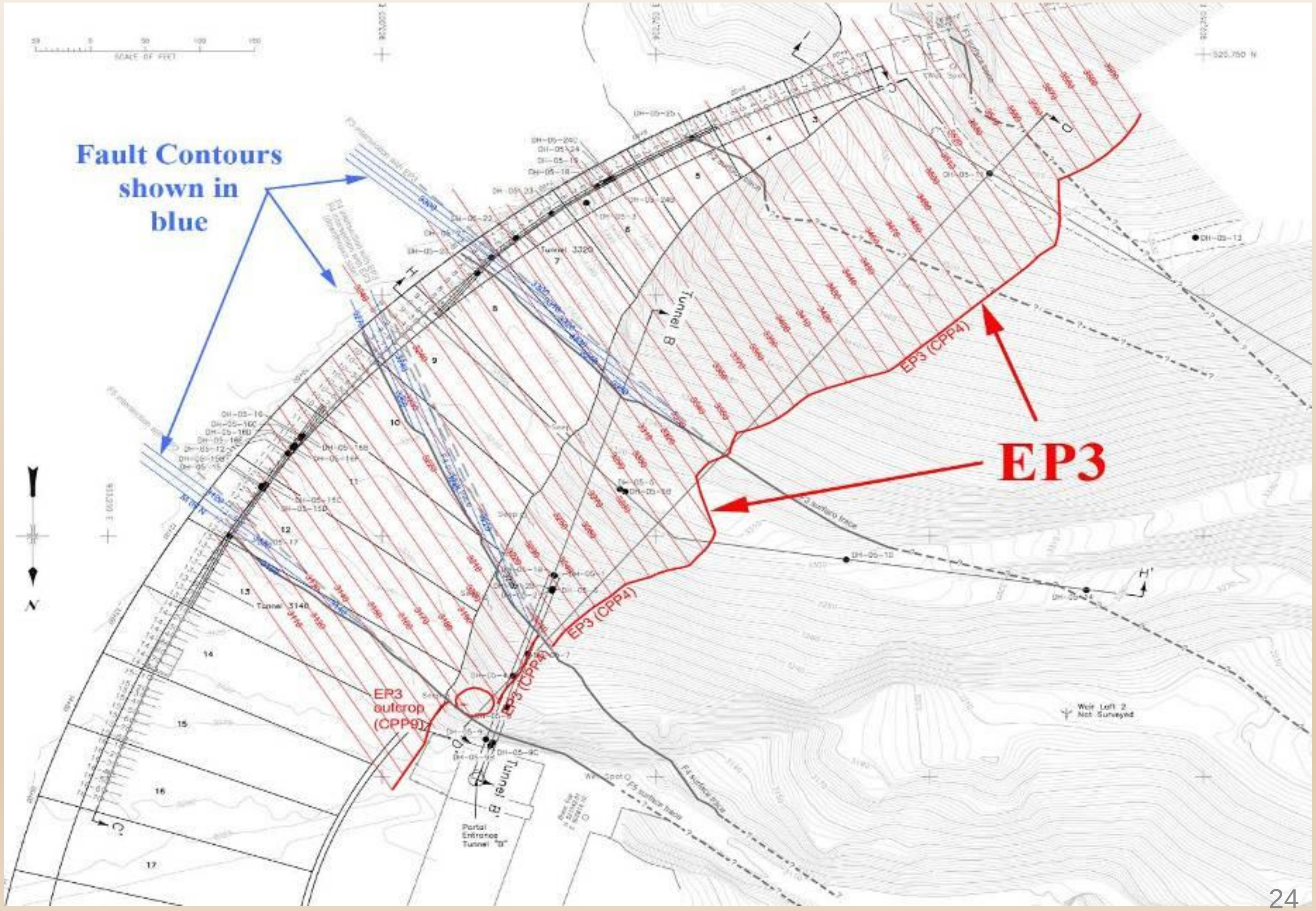
Grout Holes

Geometry of Bedrock Discontinuities

Lugeon Values from permeability tests



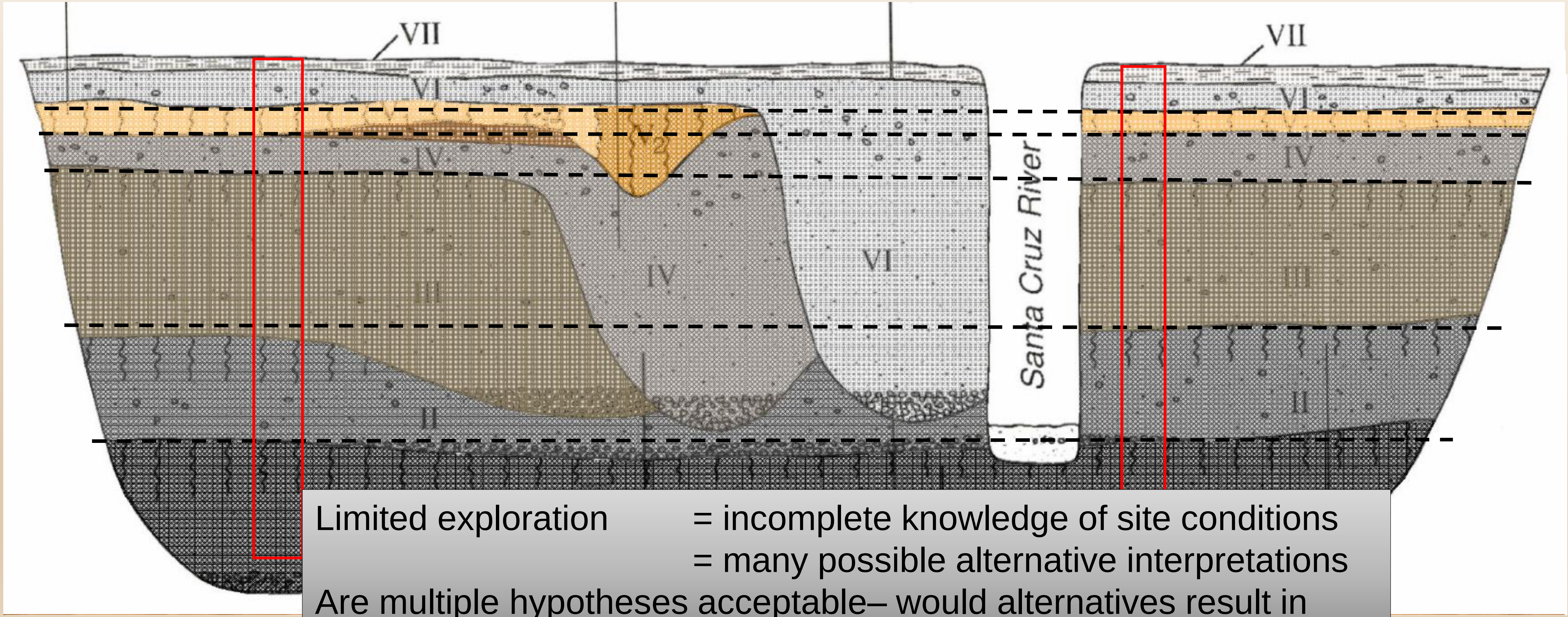
Structural Contours for Major Bedding Plane Partings and Faults



Subsurface Interpretation

Are the drillhole samples representative of the range of possible conditions?

Understand reasonable stratigraphic and lithologic variabilities



Limited exploration = incomplete knowledge of site conditions
= many possible alternative interpretations

Are multiple hypotheses acceptable– would alternatives result in different perceptions of hazard and risk?

Assessment of Levee Foundations: Requires Understanding of Depositional Processes

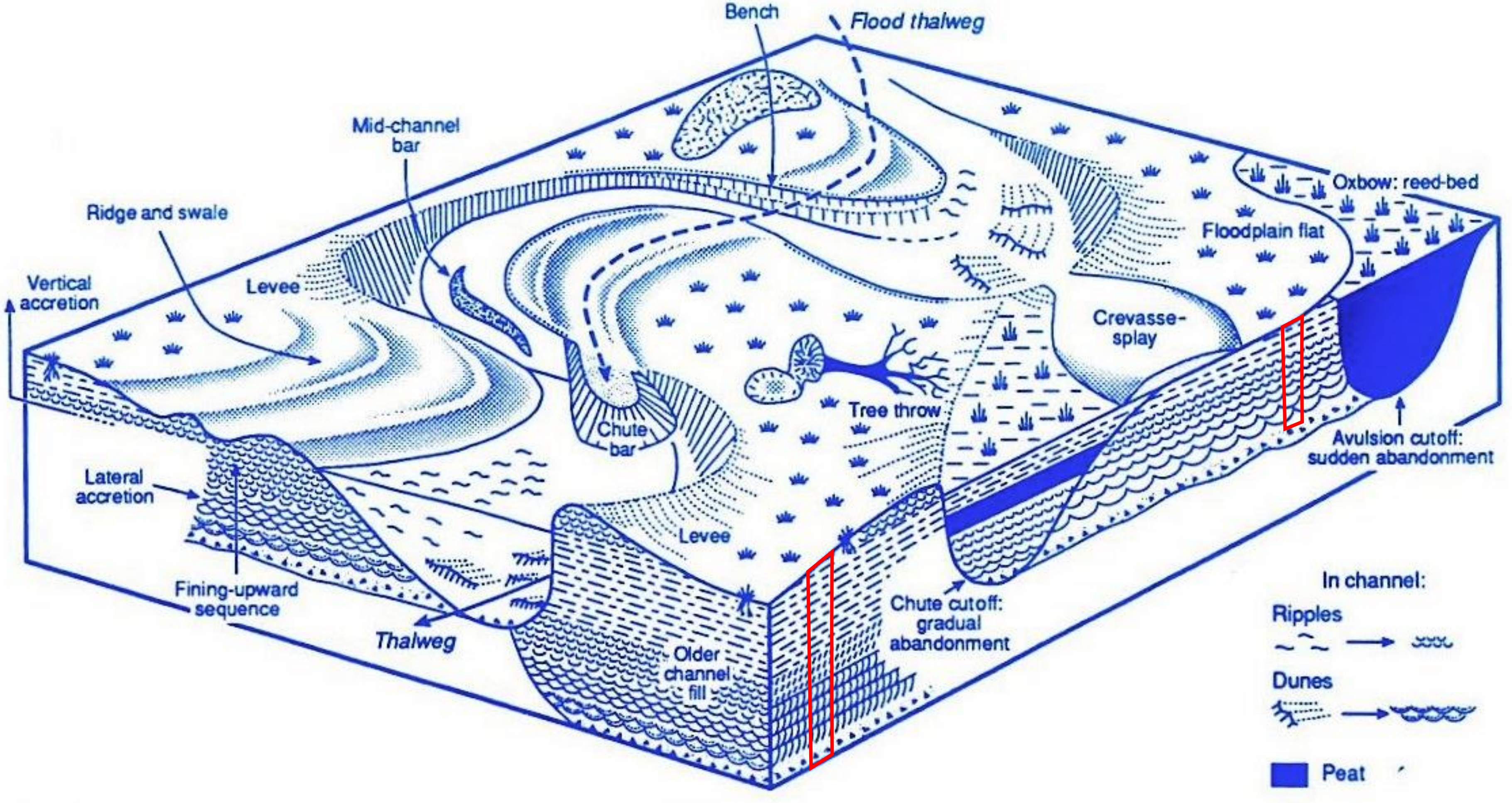
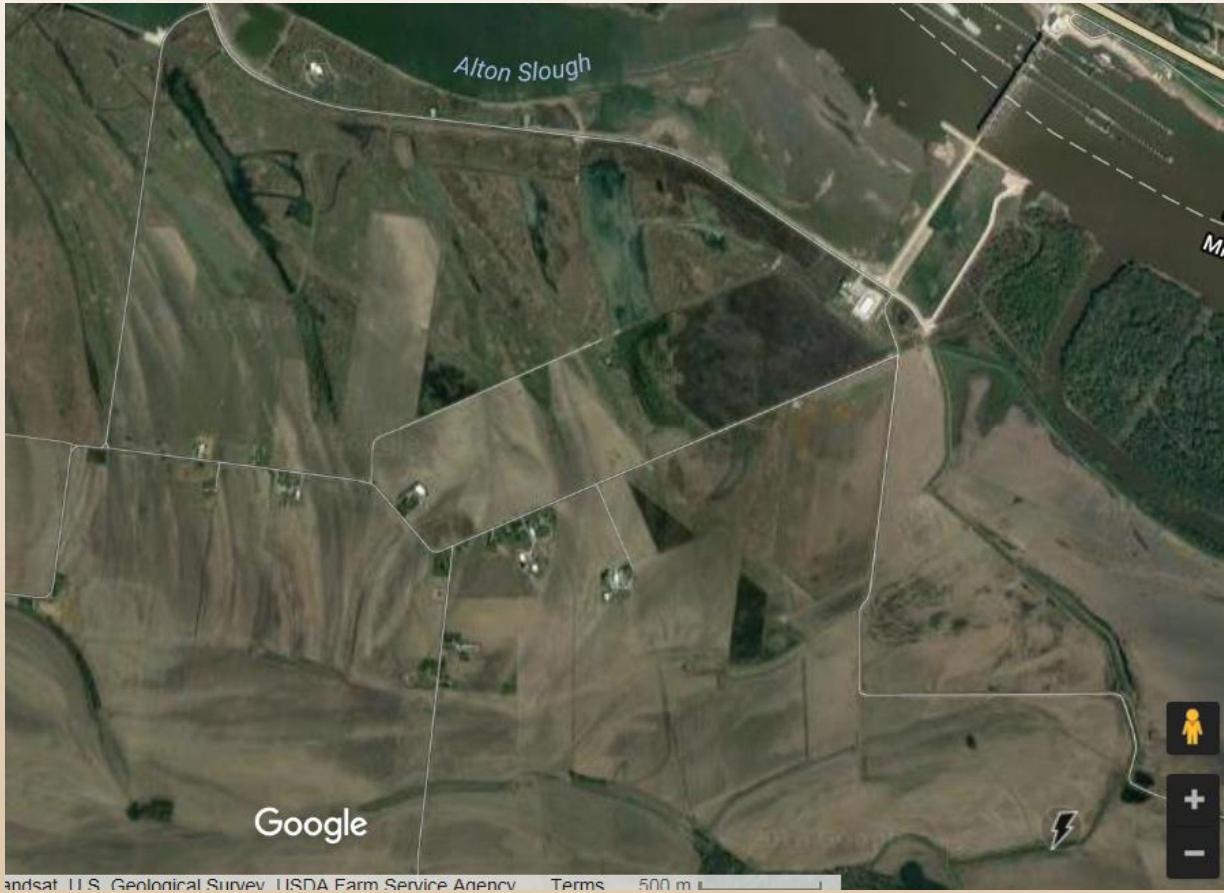


Fig. 1.1 Block diagram of landforms associated with a meandering river and its floodplain. Adapted from Allen (1965), and other sources.

Use of Satellite and Aerial Images

- Understanding of all sites is improved by use of these images
- For long sites, such as typical levees and some dams these images are a key piece of information. All on the team should review these images.
- Old geologic maps, where they exist, are invaluable.



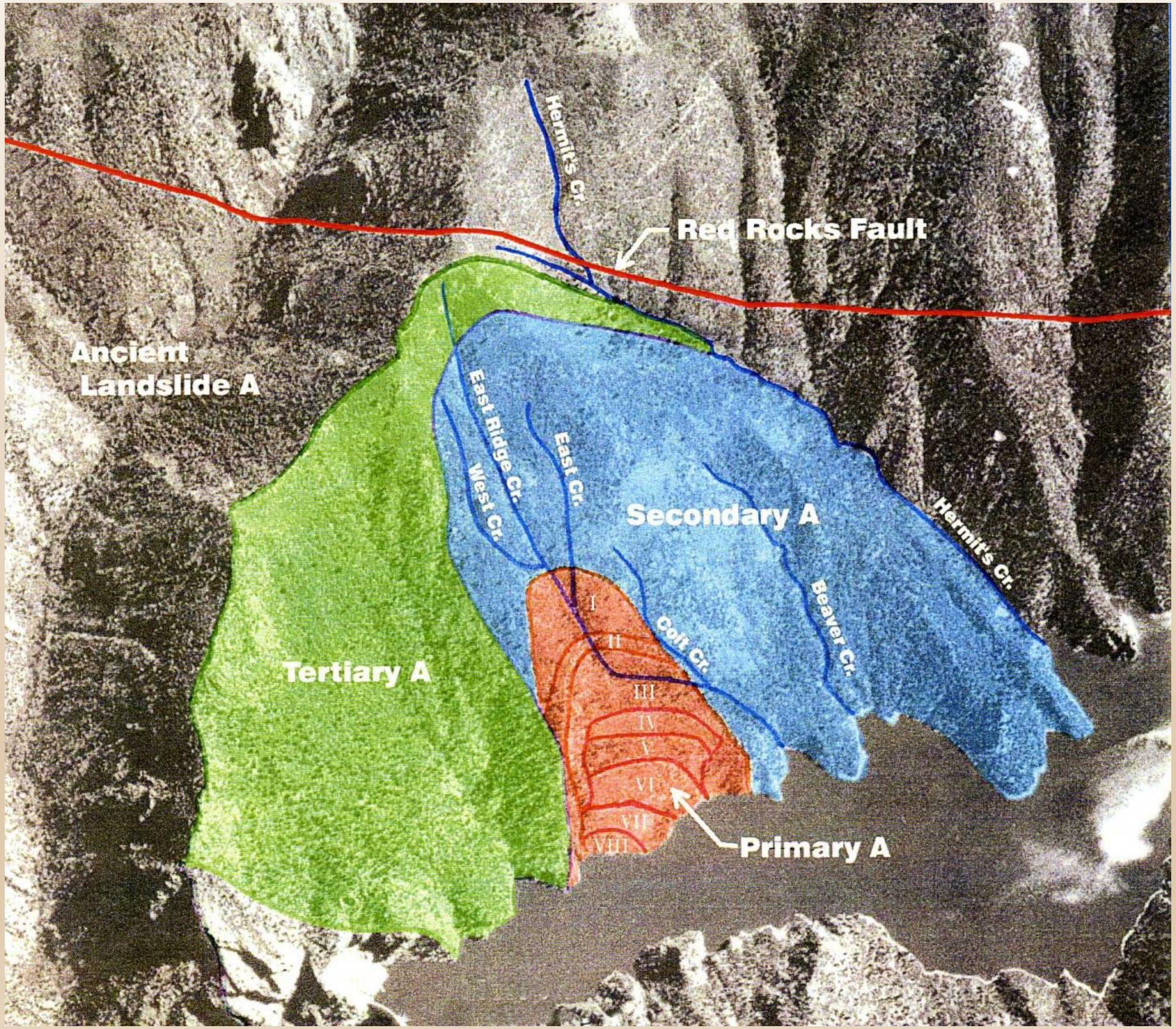
Landslide Characterization

Example Landslide Mapping-

Primary A: most active

Secondary A: less active

Tertiary A: stable



Geologic Site Characterization

<u>Goal of Site Characterization</u>

Develop understanding of subsurface conditions ("The Geologic Model"):

- Geologic model forms the basis for interpretation of data
- Model must be detailed, defensible, and verifiable
- Model must capture geologic variability at a level relevant to that particular risk assessment
- BUT not so much detail that important data are obscured or hard to interpret
- Geologic models must be verifiable- additional data must confirm, refute, or revise the model (and reduce uncertainty)

Phased Field Investigations

Adaptive management framework

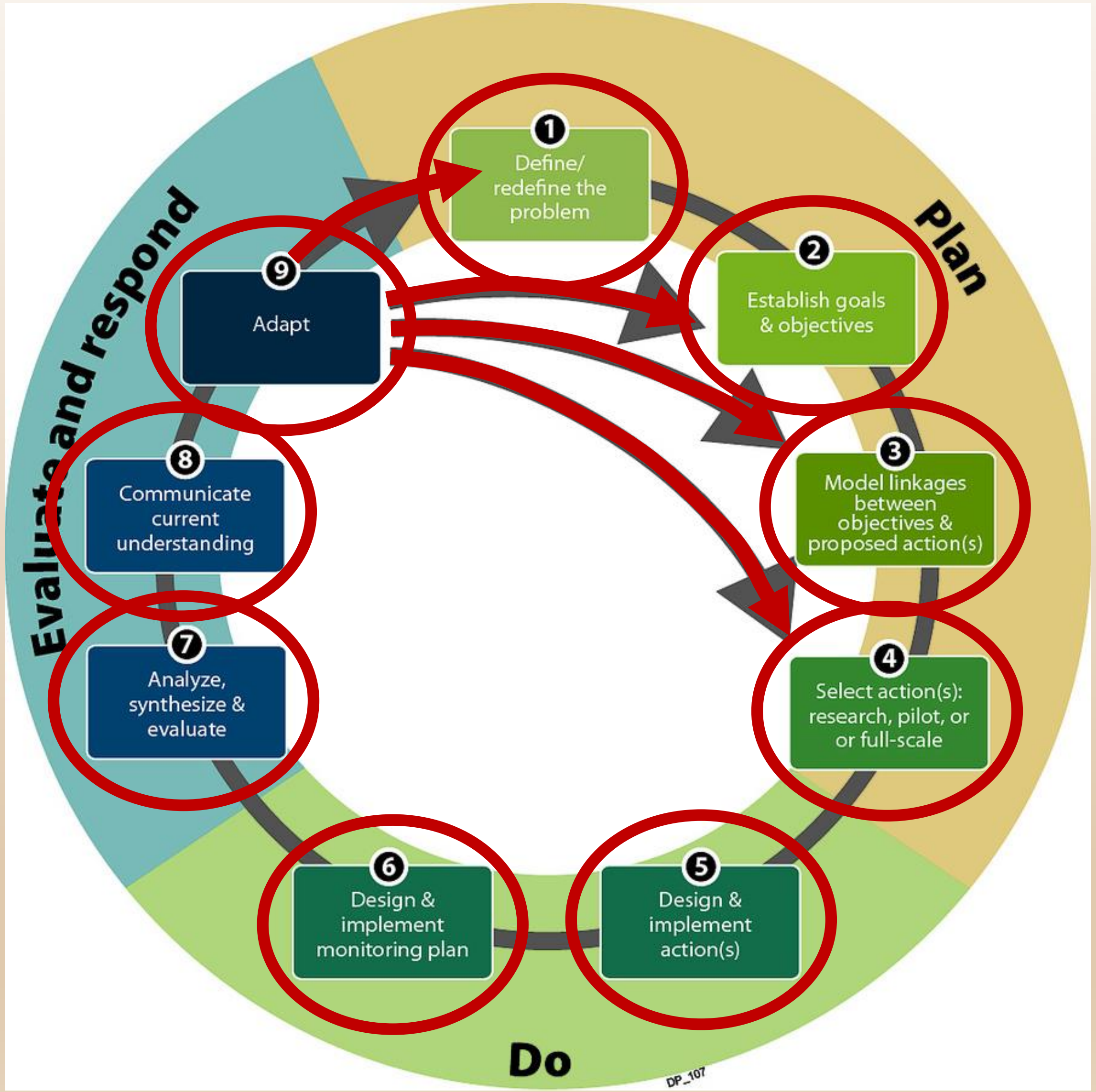
California Delta Plan
Ecosystem Restoration Program

Existing data are often limited

- Reduction in uncertainty often requires additional data collection phases
- But only on critical data gaps

Adaptive approach applies to:

- Collection and compilation of existing data
- Site characterization activities
- Analysis and reporting



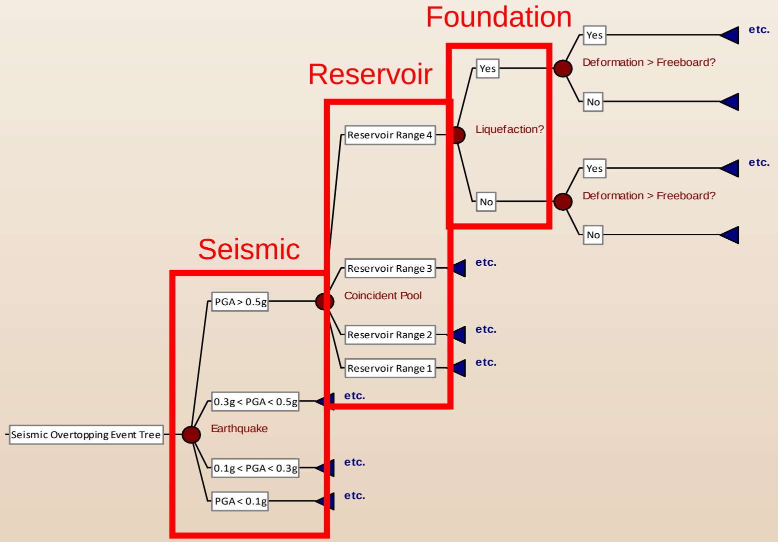
www.dfg.ca.gov/erp/adaptive_management.asp

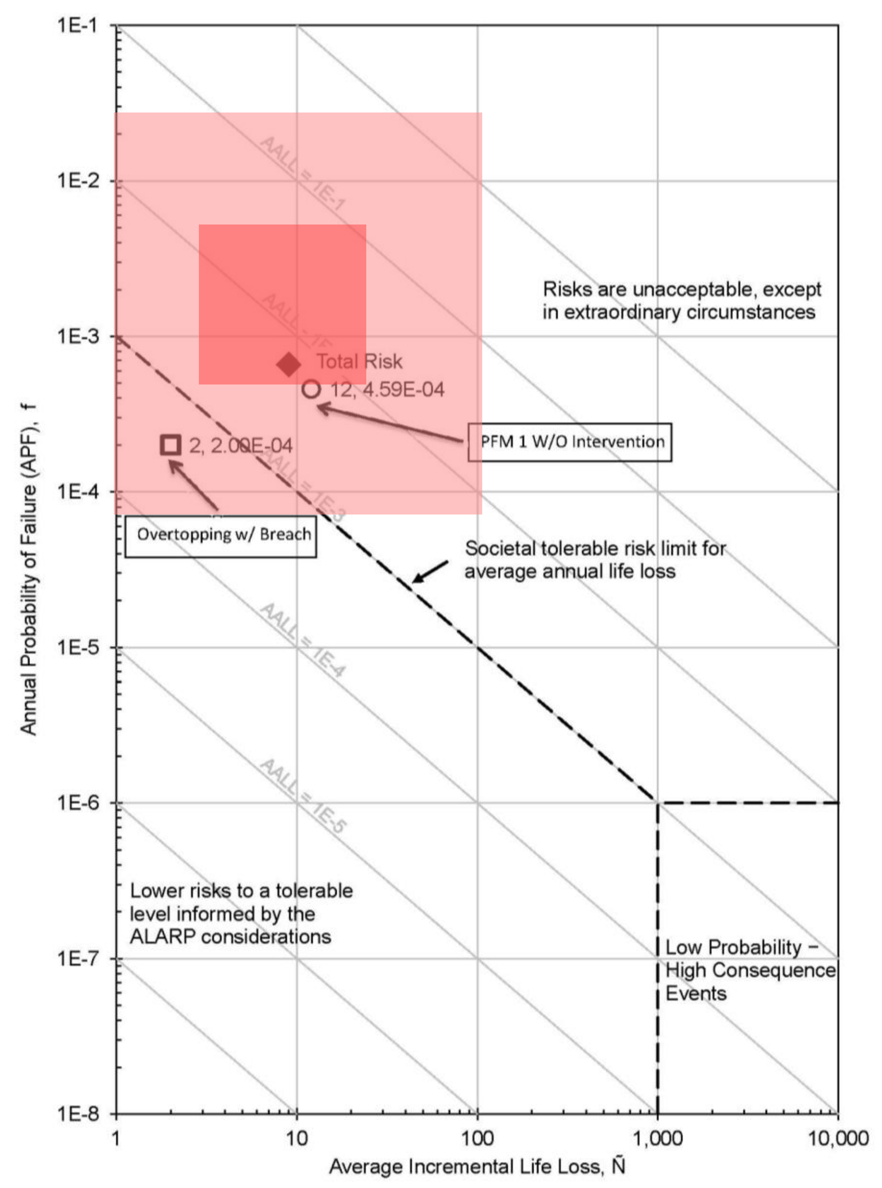
Summary:
Geologic and Geotechnical Contributions

Geologists and Geotechnical Engineers:

- Identify and Evaluate Site Characteristics and Hazards
- Contribute to Seismic, Static and Hydrologic Loading Estimates
- Capture Uncertainties in Site Conditions and Loading
- Communicate and Stay Involved in Risk Assessment

Risk Informed Decision Making
Does it make sense?





Are the geologic characterizations reasonable?

Are the geologic conclusions based on available data and analyses?

Are the uncertainties adequately portrayed?

Geologist /Geotech Engineer Roles in Dam and Levee Safety Evaluations

Collect data, understand, portray and communicate:

- Define engineering properties of dam / levee foundation in context of the geologic setting, hazards, and possible risk drivers

Work with Team Members:

- Help transfer knowledge to risk assessment teams, reviewers and decision-makers

Participate in Risk Assessment:

- Be an active member of risk teams so as to interpret conditions and make difficult estimates

Stay Involved:

- Take active role on Dam Safety Advisory Teams

Thank You